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Migration of the Army Cutworm, *Chorizagrotis auxiliaris* (Lepidoptera: Noctuidae). I. Evidence for a Migration[1]

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Abstract
Indirect evidence is presented to support the conclusion that the army cutworm, *Chorizagrotis auxiliaris* (Grote), migrates from the Great Plains to the Rocky Mountains during the spring and the same individuals return to the Plains in the fall. Spring activity occurs progressively later from east to west, the delay being greater than that caused by emergence but commensurate with flight potential of the moth. Flight is predominately from east to west and a constant turnover of moths occurs at all locations on the Plains. Seasonal occurrence in the mountains coincides with the period of inactivity on the Plains, during which fat reserves increase. Summer survival is unlikely on the Plains and little or no reproduction occurs in the mountains. Fall populations on the Plains are correlated with oversummering populations in the mountains but not with populations at any location on the Plains the preceding spring.

The army cutworm, *Chorizagrotis auxiliaris* (Grote), is widely distributed on the Great Plains from Canada to Mexico. Despite the long economic history of the species and many biological studies, the summer behavior of the moth has never adequately been explained.

Two flights of moths, as indicated by light traps, occur annually. In Nebraska, large flights occur in May and June and again in September and October. The spring flight may occur as early as April in Arizona or as late as July in Canada, but the fall flight occurs more or less simultaneously throughout the species' range. In Nebraska there are 30–55 days in July and August when specimens are neither collected in light traps nor found in the field. Although the duration of this period of apparent absence on the Plains increases toward the south and becomes shorter or nonexistent in Canada, the bimodal seasonal flight pattern persists throughout the Great Plains.

Conflicting; explanations have been offered for this seasonal flight pattern. Originally, 2 broods were hypothesized (Gillette 1904, Johnson 1905), but Gillette recognized that egg development does not occur during the spring, an observation confirmed by all subsequent workers. Seamans (1928) reported finding moths in the field in Canada and concluded that they estivated in protected places.

Pepper (1932) was unsuccessful in carrying caged moths through the summer in Montana. He observed unidirectional flights of moths and was the first to suggest that a migration to nearby mountains might occur. Several workers (Gillette 1898, 1904; Walkden 1950; Chapman et al. 1955) have reported moths at high altitudes in the Rocky Mountains during the summer. In personal communication, other workers (Marvin, Nagel, Wygant) have reported similar observations. Jacobson and Blakeley (1959) and Jacobson (1960), in laboratory studies, found that temperature and photoperiod affected adult longevity and duration of the pre-oviposition period, but their results do not satisfactorily explain an in situ estivation on the Great Plains. In this paper I shall present evidence supporting a migration hypothesis to account for the apparent seasonal and geographical distribution of the species.

Morphological Variation

The army cutworm is widely distributed throughout Western North America from Canada to Mexico on both sides of the Continental Divide (see U.S. Department of Agriculture (1958) for a distribution map). Moths sometimes occur abundantly in such diverse habitats as the desert region near Mesa, Arizona, and above tree line in the Rocky Mountains. If these moths result from locally reproducing populations, genetic (and morphological) differences might be expected. Collections of adults were obtained from a wide portion of the species range in 1959 and examined for morphological variation.

The army cutworm adult is sexually dimorphic in wing color; extreme and similar variations in other wing markings occur in both sexes. Many names have been applied to these forms, four of which *(auxiliaris*, *agrestis*, *introferens*, and *montanus*) are currently recognized and are usually separable. While only Mansbridge (1897) mentions the occurrence of a melanic form, melanism is not uncommon and is often so pronounced as to preclude separation into the named forms. Figure 1 represents my interpretation of the names which have been applied and follows that of Forbes (1954).

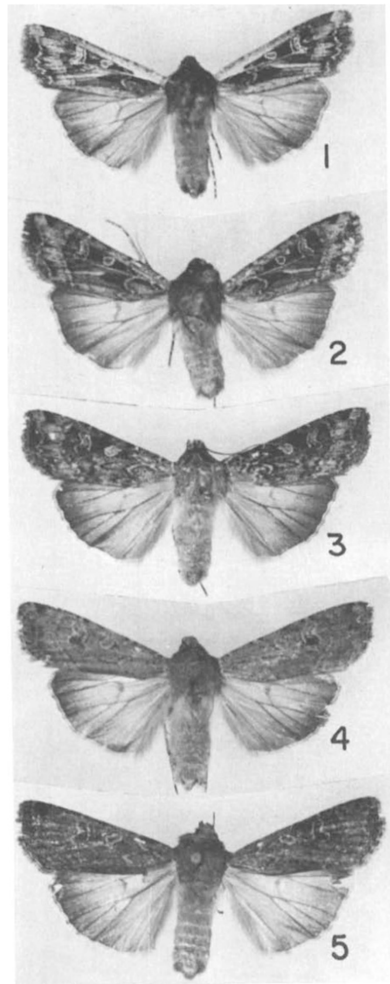

Figure 1. Color forms of the army cutworm moth, *Chorizagrotis auxiliaris*. 1, *auxiliaris*; 2, *introferens;* 3, *montanus*; 4, *agrestis*; 5, melanic.

Smith (1890) figures differences in male genitalia of some of these forms which at that time were considered species. Cook (1930a) recognized that Smith must have made errors in his identifications. Wolley-Dod (1918) states that he reared forms *auxiliaris* and *agrestis* from a single parent, and Cook (1930a) reported rearing *agrestis* from *auxiliaris*; Cook synonymized *introferens* and *auxiliaris*. Although there is no doubt that these are merely 2 forms without nomenclatural validity, I have never seen sufficient intergradation between them to preclude separation, and I retain the names for descriptive purposes.

The original type-specimens of these forms came from widely scattered locations, and the extent of geographical variation has not been determined. Cook (1930a), in describing the form *montanus*, thought this form might be more common in the northern portion of the species range. Table 1 summarizes data on geographical abundance of these color forms.

Table 1. Geographical abundance of color forms of army cutworm

			Number examined		Percent of total[a]									
					♂					♀				
Location	Year	Collection method	♂	♀	Ag	Mo	In	Au	Me	Ag	Mo	In	Au	Me
Hays, Kans.	1959	Light	74	112	13	27	43	12	5	9	28	50	12	1
Garden City, Kans.	1959	Light	396	467	13	27	48	11	1	16	23	45	14	2
Rocky Ford, Colo.	1959	Light	319	394	18	24	46	11	1	12	23	49	13	3
Greeley, Colo.	1959	Light	76	118	19	16	48	16	1	18	24	46	9	3
Springfield, Colo.	1959	Light	183	89	13	24	45	16	2	23	21	42	10	4
Kearney, Nebr.	1959	Light	188	246	26	18	44	11	1	14	22	56	14	4
	1963	Light	460	573	20	20	46	12	1	15	25	47	11	2
	1964	Light	841	1155	19	22	47	11	1	19	23	44	13	1
N. Platte, Nebr.	1959	Light	387	385	23	15	45	16	1	19	20	45	14	2
	1959	Reared	116	112	25	22	43	10	0	23	21	42	12	4
	1960	Light	548	566	27	16	42	12	3	18	20	45	14	3
	1963	Light	2020	2133	19	22	44	13	2	17	25	44	12	2
	1963	Field	831	837	19	22	45	12	2	17	22	46	13	2
	1964	Light	3624	3717	18	23	46	12	1	18	22	46	13	1
	1965	Light	1000	1167	18	22	46	13	1	17	23	47	12	2
Ogallala, Nebr.	1963	Light	1209	1284	19	22	45	12	2	20	23	43	12	2
	1964	Light	650	932	17	25	46	12	0	20	20	46	13	1
Alliance, Nebr.	1959	Light	167	248	19	22	46	11	2	17	19	46	15	3
Bushnell, Nebr.	1963	Light	1632	1681	19	21	45	13	2	18	23	44	13	2
	1964	Light	1478	1963	19	16	50	14	1	18	25	44	12	1
Scottsbluff, Nebr.	1959	Light	432	605	21	21	43	12	3	22	21	41	14	2
Cheyenne, Wyo.	1963	Light	1999	2079	20	22	45	11	2	17	24	44	13	2
	1964	Light	1496	1847	20	21	46	13	0	17	23	45	14	1
Centennial, Wyo.	1959	Light	152	196	22	22	45	11	0	16	24	37	14	5
	1963	Light	960	1072	20	22	45	12	1	19	23	44	12	2
Twin Falls, Idaho	1959	Light	121	192	24	17	45	12	2	20	24	37	14	5
Filer, Idaho	1959	Light	167	260	24	18	40	13	5	16	20	43	16	5
Rupert, Idaho	1959	Light	341	64	16	23	46	14	1	23	22	43	11	1

a. Ag = *agrestis*, Mo = *montanus*, In = *introferens*, Au = *auxiliaris*, Me = melanic

Ratios of color forms were found to be very similar throughout the range. The greatest variation occurs in abundance of *montanus* and *agrestis*. These forms intergrade to some extent, and part of the separation was arbitrary. That part of this variation which is genetically determined and that portion which may be environmentally induced is still in doubt. Cook (1930a) suggests that temperature may affect color expression. The ratios also change little from year to year as indicated by large collections examined from various localities in Nebraska and Wyoming over a period of several years.

Other characters were examined and a partial summary of results is given in Table 2. Variation was not found in the male genitalia which could be correlated with either color forms or geographical distribution. No secondary sexual differences were observed in leg spines; therefore measurements on both sexes are combined in Table 2. Setal duplication was frequently observed but not included in counts. Variation in chaetotaxy from right to left side of the body of a single individual was often as great as differences between moths from different locations.

Table 2. Morphological variation in adults of the army cutworm, *Chorizagrotis auxiliaris*, collected in 1959

Source	No. moths examined		Mean wing length (mm)	Mean no. spines in indicated row (left leg)					♂ Corona spines
				Fore tibia	Fore metatarsus		Middle tibia		
	♂	♀		outer	Center	Outer	Center	Outer	
Mesa, Ariz.	4	1	19.2	8.0	12.0	9.0	13.0	9.0	
Center, Colo.	27	16	20.5	7.4	13.4	9.6	12.4	9.8	14.9
Rocky Ford, Colo.	11	28	20.5	7.4	12.9	9.4	12.2	9.3	
Estes Park, Colo.	0	4		7.6	11.0	8.7	11.7	8.5	
Lulu Pass, Colo.	16	34		7.3	11.6	8.9	12.0	8.5	15.0
Garden City, Kans.	31	31	19.9	7.2	10.6	9.2	12.3	9.1	15.2
Manhattan, Kans.	7	12	20.8	7.1	11.6	9.2	12.5	9.8	
Lincoln, Nebr.	11	15	20.1	7.4	12.2	9.2	12.5	9.3	
North Platte, Nebr.	136	199	20.0	7.5	12.4	9.2	12.2	9.4	15.4
Alliance, Nebr.	14	17	20.0	7.2	11.9	9.3	12.4	9.4	
Scottsbluff, Nebr.	0	235	20.0	7.1	11.7	9.0	11.6	9.2	
Centennial, Wyo.	29	24	20.4	7.2	12.8	9.4	12.2	9.4	
Med. Bow Pk., Wyo.	15	14		7.3	11.7	9.6	11.9	9.6	15.0
Laramie Pk., Wyo.	10	16		7.2	11.5	9.1	11.9	9.3	15.5
Rupert, Idaho	21	24	21.1	7.4	12.3	9.3	12.4	9.7	15.6
Twin Falls, Idaho	6	3	21.1	7.2	12.4	9.2	12.0	9.5	14.5
Walla Walla, Wash.	24	20	19.9	7.3	12.1	9.6	12.3	9.3	15.4
Lethbridge, Alberta	18	19	20.7	7.0	12.0	9.5	12.1	9.2	15.7

The only characters which differed significantly were size and weight characters. In several cases, specimens were available from only a small portion of the flight period. When material was available over an entire season, variation greater than that occurring between localities was often encountered between dates within localities. Jacobson and Blakeley (1959) found that larval diet affects both rate of development and pupa size. This seasonal variation, which is probably environmentally induced, will be discussed further in a later section.

The demonstration of clines, particularly from east to west, would negate—or severely complicate—the hypothesis that moths at high elevations in the mountains might be migrants from the Great Plains. Such clines were not found. Absence of east-west clines, while not necessarily supporting a migration hypothesis, is at least suggestive of a continuous gene pool.

Flight Period in Nebraska and Wyoming

Numerous black-light traps were operated in Nebraska and Wyoming from 1959 to 1965. The spring flight tends to occur later in the west than in the east (as shown in Fig. 2). Is this seasonal distribution of moths indicative of a migration? Or can geographical differences be explained solely by delayed emergence of moths in the west?

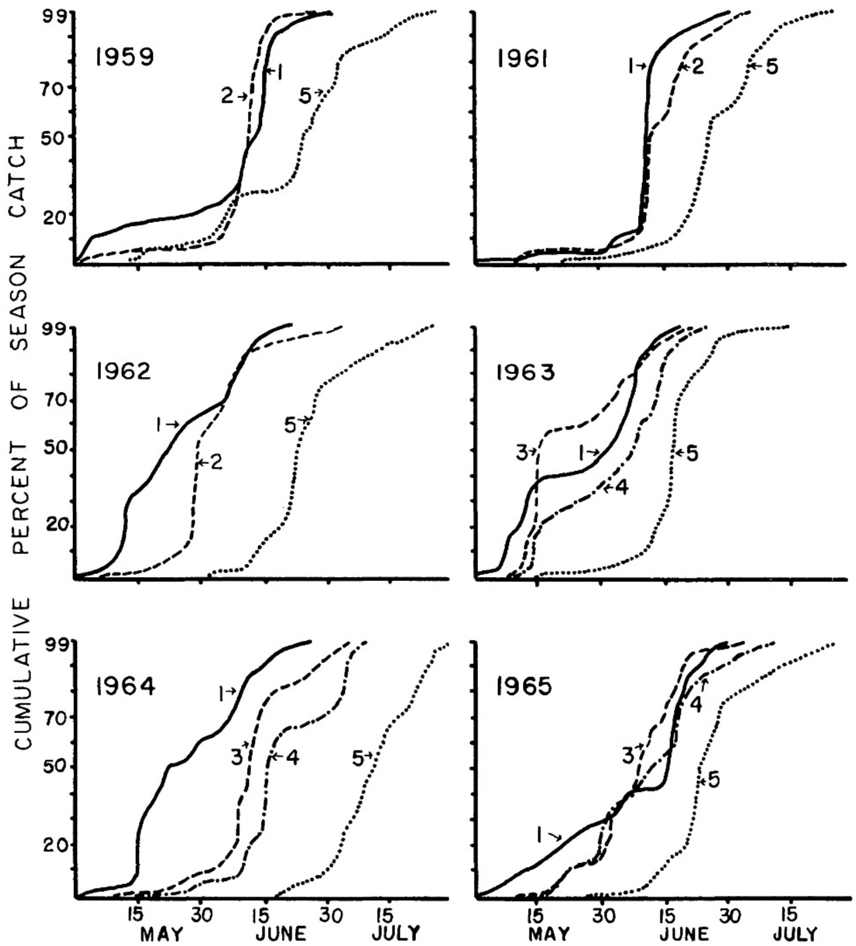

Figure 2. Seasonal occurrence of army cutworm moths at light traps during spring at locations numbered from east to west; 1, North Platte, Nebraska; 2, Scottsbluff, Nebraska; 3, Bushnell, Nebraska; 4, Cheyenne, Wyoming; 5, Centennial, Wyoming.

During most of this study, methods were unknown for determining when moths emerged at each location, and thus for separating a possible migration from a delayed emergence in the west. In 1963, presence or absence of the meconium was found to be a useful character for dividing moths into 2 age groups. Moths become active the day of emergence; the meconium is not voided immediately but over a period of 1 or 2 days (perhaps slightly longer under weather conditions unfavorable for activity). Moths retaining the meconium at the time of collection must be relatively young, and from previous flight studies (Koerwitz and Pruess 1964) it seems highly unlikely that these moths could be migrants. In 1964 moths were examined throughout the spring flight period at all locations for presence or absence of the meconium. Results are summarized in Table 3.

Table 3. Percent of army cutworm moths which possessed meconium taken in light traps, 1964

Location	Number examined	Percent with meconium
Kearney, Nebr.	2522	37
North Platte, Nebr.	7701	46
Ogallala, Nebr.	1840	46
Chappell, Nebr.	1366	30
Bushnell, Nebr.	5091	25
Cheyenne, Wyo.	6553	5
Laramie, Wyo.	221	0
Centennial, Wyo.	218	0

There was a general trend for proportion of moths possessing the meconium to decline from east to west. Although emergence may be somewhat later in the west, as indicated by catches of moths still possessing the meconium, there seems to be an excess of moths in the western portion of the range which do not possess the meconium. As suggested by Figure 3, most of this excess of "old" moths occurs late in the season. Two explanations are possible: (1) there is a longer activity period following emergence in the western part of the range, or (2) the moths collected late in the season in the west came by migration from some other area. Since moths possessing the meconium were not collected at either Laramie or Centennial, Wyoming, nor have larvae been found at these locations, a locally emerging population at those locations seems unlikely.

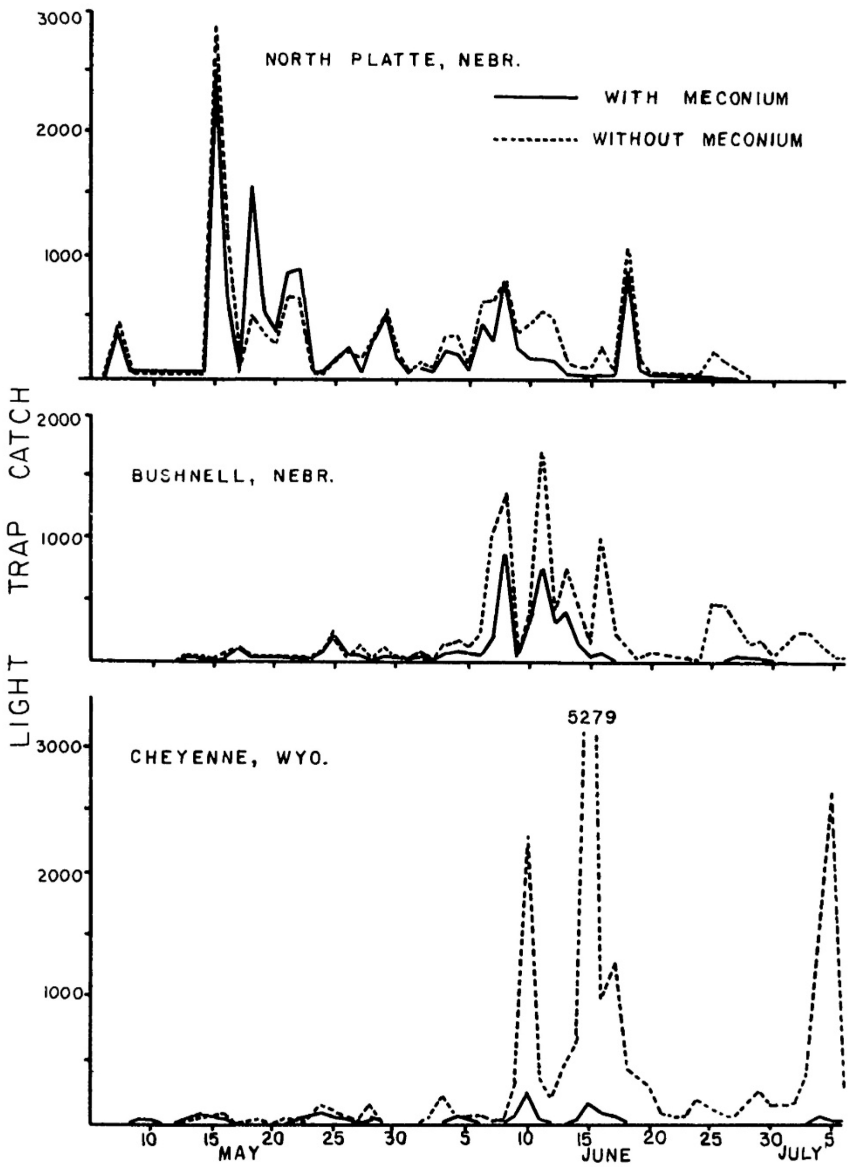

Figure 3. Daily light-trap catches of recently emerged army cutworm moths (with meconium) vs. moths of indeterminate age (without meconium) at 3 east-to-west (top-to-bottom) locations in 1964.

Table 4 summarizes the periods of apparent absence of moths at 3 locations arranged from east to west. The last spring catch occurs consistently later in the west. Although there is a tendency for the fall flight to begin earlier in the west, the chronological sequence is not so invariable as in the spring. Fall activity is related to certain weather conditions and will be discussed at greater length in a future paper.

Last spring and first fall records are usually based on single individuals; the bulk of the population is seemingly absent from the Great Plains, the area of emergence, for longer periods than indicated in Table 4. At Centennial, moths are present most of the summer and a few miles west of Centennial, at higher elevations, activity is continuous during the summer. Only at high elevations in the mountains is the activity pattern unimodal. Peak activity in the mountains occurs during the summer period of inactivity on the Plains. Since the evidence is that moths do not emerge in the mountains, their presence there is best accounted for by migration from some other area.

Table 4. Periods (days) of inactivity of army cutworm moths as indicated by absence from light-trap catches. Dates of last spring catch and first fall catch are given in parentheses.

Year	North Platte, Nebr.	Scottsbluff, Nebr.	Centennial, Wyo.
1957	34 (July 21; Aug. 25)		
1958	34 (July 19; Aug. 23)		
1959	39 (July 15; Aug. 24)	37 (July 23; Aug. 30)	5 (Aug. 5; 11)
1960	41 (July 16; Aug. 27)	28 (July 29; Aug. 27)	
1961	34 (July 21; Aug. 25)	33 (July 23; Aug. 26)	7 (Aug. 5; 13)
1962	54 (July 8; Sept. 1)	32 (July 19; Aug. 21)	0[a]
1963	47 (July 4; Aug. 21)	54 (July 4; Aug. 28)	8 (Aug. 9; 18)
1964	47 (July 14; Aug. 31)	26 (July 17; Aug. 13)	5 (Aug. 9; 15)
1965	55 (July 15; Sept. 9)	34 (July 23 ; Aug. 27)	0[a]
Means	43	35	4

a. Flight continuous through the summer.

Summer Survival of Moths on the Great Plains

Can moths survive the summer on the Great Plains? In Canada and Montana, moths are sometimes found throughout the summer, but even in the most northern portion of the range there is a definite bimodal distribution as indicated by light-trap catches. Cook (1930b) stated that moths fly late at night in the summer in Montana but only at temperatures well below 60°F. He further pointed out that such activity occurs only during cool summers. Seamans (1928) found what he termed estivating moths in the field in Canada, but it is not clear whether those moths survived the summer. Cooley (1916) reported that a few moths lived in cages until September 21 in Montana, but he was unable to find moths in the field during the summer. Pepper (1932), also working in Montana, was unsuccessful in carrying caged moths through the summer in the field.

In Nebraska, I have consistently found moths in the field during periods of activity in both the spring and fall. In the spring they frequently enter buildings. In open fields they usually crawl under clods or trash during the day and are especially abundant in wooded areas where they hide under leaves on the ground. Despite a diligent search, I have never found living moths in Nebraska from mid-July to late August. To determine if moths might survive Nebraska summers, moths were caged in the field at North Platte in 1958 and 1959. Cubical cages, 1 yard on a side, were constructed of wood and screen cloth. Pieces of bark or shingles were loosely stacked to provide shelter, and a dilute mixture of honey and water was kept constantly available for food. Each year 2 cages were placed in a densely wooded area, and in 1959 two additional cages were placed in an open field. About 200 moths were placed in each cage in mid-June, just prior to termination of activity in the field.

During the first week following caging, considerable activity occurred at dusk, when the moths became active and fed. Activity gradually diminished and living moths were not found after July 20, 1958. In 1959, 6 live moths were found when a cage was dismantled on July 29. Further activity was not noted in any cage and living moths were not present on August 16, when the 3 remaining cages were examined. While survival in cages slightly exceeded the activity period recorded by light traps each year, longevity was far shorter than that required for a summer estivation on the Plains.

Survival of moths varies inversely with temperature. Pepper (1932) found that moths could survive long periods at low temperatures but are short lived at temperatures approaching those occurring on the Plains during the summer. This observation was confirmed by Jacobson and Blakeley (1959) and Pruess (1963). If any moths oversummer in Nebraska, they must do so by means of an inactive estivation in a more favorable, and yet undiscovered, habitat than that provided in cages.

Summer Populations in the Rocky Mountains

During the period of absence from the Plains, moths become abundant at high altitudes in the Rocky Mountains. In southern Wyoming, greatest concentrations occur near tree line (about 3200–3350 m) and these moths are active throughout the summer. During the day, moths can be found hiding under rocks in dry places near alpine meadows. Diurnal activity is sometimes noted at high altitudes.

Moths sometimes occur throughout the summer at Centennial (2740 m), but most years there is an upslope movement during the summer, possibly in response to changing nectar sources. Those years when moths are found at lower altitudes are usually cool and wet. During such seasons, light traps show a minor fall activity peak at Centennial. Often moths remain at high altitudes with little down-slope movement in the fall, and during those seasons fall catches in the Centennial light traps are light despite the large populations occurring within a few miles at higher altitudes.

On only 1 occasion (August 9, 1960, at Lulu Pass on the north edge of Rocky Mountain National Park in Colorado) have I found what may have been an inactively estivating population. Although it was a warm, sunny day, these moths were completely inactive. All had large fat accumulations, the average abdominal weight exceeding that of any other collection made. Moths collected at high altitudes during the summer tend to be heavier than moths at lower elevations. This difference has been noted between collections made during several years at Centennial and only a few miles west near Mirror Lake, some 460 m higher (see next section).

Development of a Fat Body

Moths, following emergence on the Plains, have sizable fat deposits. If an in situ estivation occurs, the reserves present at time of emergence, or accumulated prior to entering estivation, must be sufficient to carry the moth through the summer. Table 5 presents data on the biochemical composition of moths. The spring data include 3 groups of moths. Groups A and B are typical of the bulk of the population; Group C represents only 1%–2% of all moths taken at light.

Table 5. Mean weights and chemical composition of female army cutworm moths collected at North Platte, Nebraska, in 1962

	Spring populations[a]							
	A		B		C		Fall	
Variable	mg	%	mg	%	mg	%	mg	%
Total body weight	51.3		58.7		86.0		56.4	
Head and thorax	29.0		35.6		37.8		29.4	
Fat	0.7	2.5	1.6	4.5	6.9	18.2		
Protein	21.3	73.6	26.5	74.4	26.3	69.7		
Glucose + glycogen		0.043		0.041		0.058		
Abdomen	22.3		23.1		48.2		27.0	
Fat	7.5	33.8	5.2	22.4	30.9	64.2	10.8	40.1
Protein	12.8	57.2	15.9	68.8	14.1	29.2	11.8	43.8
Glucose + glycogen		0.057		0.046		0.099		2.52

a. Mean wing lengths (mm): A, 20.5; B, 20.8; C, 22.0.

Moths of Group B were structurally larger than A, but had slightly lower fat reserves in the abdomen. Since both of these groups contained smaller fat deposits than fall-collected moths, they could not constitute an oversummering population on the Plains. Group C contains moths which are more likely candidates for summer survival.

Dry weight of the abdomen is a good indicator of fat deposits. Mean abdomen weight, exclusive of fat, was 14.8 mg for the smallest moths, A, and 17.9 mg for B. The greater abdomen weight of C was due entirely to increased fat deposits. Mean abdomen weight for all moths collected in the spring is less than the mean weight for all fall-collected moths (Fig. 4). It is possible to reconcile this result by assuming differential survival, permitting only those moths with large fat bodies to survive the summer. But absolute maximal abdominal weights of fall-collected moths are invariably greater than maximal weights of spring-collected specimens. In 1963, 7% of the moths collected during the fall flight at North Platte were heavier than *any* moth collected during the spring. I can scarcely envision an accumulation of body reserves during estivation. Furthermore, many moths collected during the fall have largely completed oviposition, and it is reasonable to assume that their stored reserves have been depleted in the process.

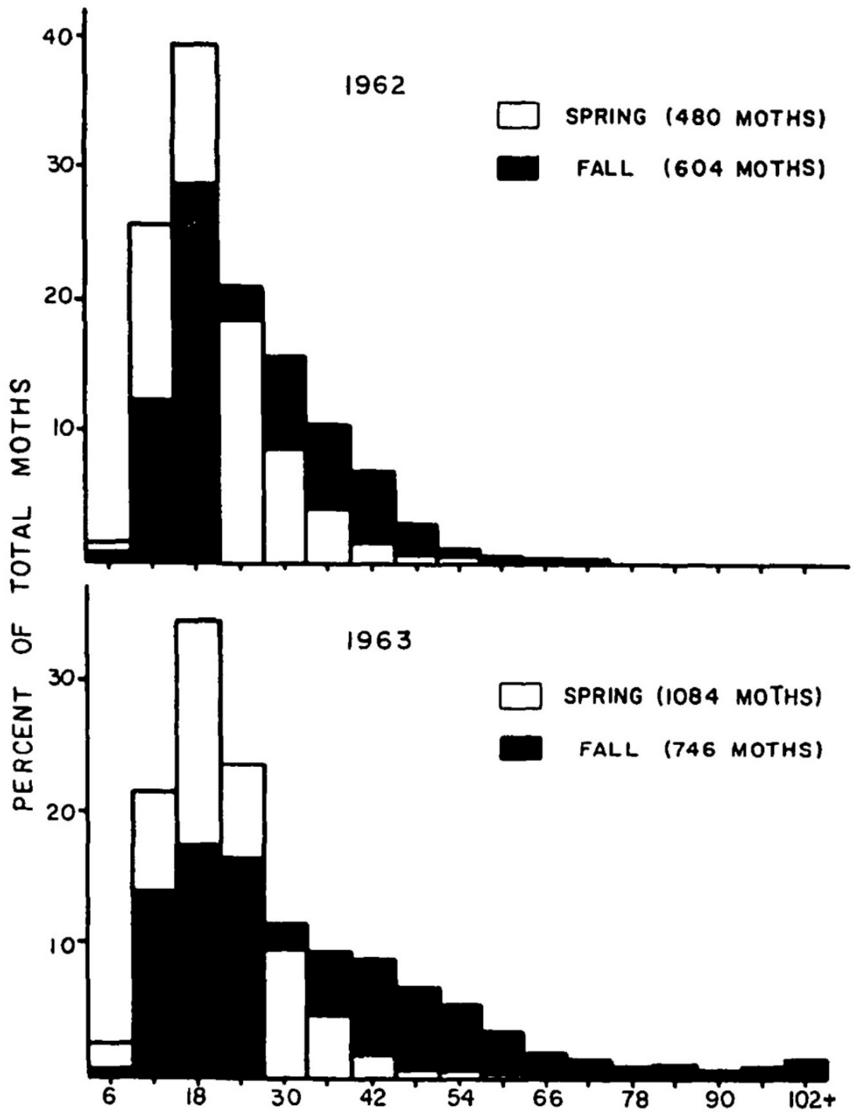

Figure 4. Frequency distribution of abdomen weights of spring- vs. fall-collected female army cutworm moths at North Platte, Nebraska.

Few unmated moths are collected on the Plains during the fall. Data on these moths, though meager, provide some insight into the reserves present prior to oviposition. Abdominal weights of 12 unmated ♀ collected in 1963 averaged 77.4 mg, far in excess of maximal weight of any moth collected in the spring and much greater than the mean weight of all fall-collected females. Such fat deposits are comparable to those found in moths in the Rocky Mountains during the summer. Mean abdominal weight of 26 ♀ collected near Medicine Bow Peak, Wyoming, in 1963 was 98.5 mg. Mean abdominal weight of 7 moths collected at Centennial in August 1962, was 58.6 mg vs. 43.6 mg for 11 unmated 2 collected at North Platte in the fall. Although unmated females collected on the Plains during the fall tend to have smaller fat reserves than moths collected in the mountains, a weight loss during migration would not seem unreasonable. To postulate a weight gain during estivation on the Plains is less tenable.

Changes in Composition of Locally Emerging Populations

If a migration occurs, the population present at any location would be expected to change from day to day. Do such changes occur and, if so, can they be recognized?

Figure 5 compares mean daily dry abdomen weights for females still possessing the meconium, and thus assumed to be recently emerged, with other moths of unknown age at North Platte and gives mean wing length for moths of unknown age. Average moth size, based on either wing length or dry weight, varied significantly from day to day. The seasonal distribution of weights for moths with and without meconium closely parallel each other. Daily differences seem to be due solely to emergence weights. Part of this variation might be attributed to gains or losses in weight following emergence if it were not for the fact that wing length fluctuates in a similar manner. Samples taken of moths hiding in the field and feeding on flowers gave the same results. I have been unable to collect moths on the Plains during the spring with larger fat deposits than those known to be present at time of eclosion.

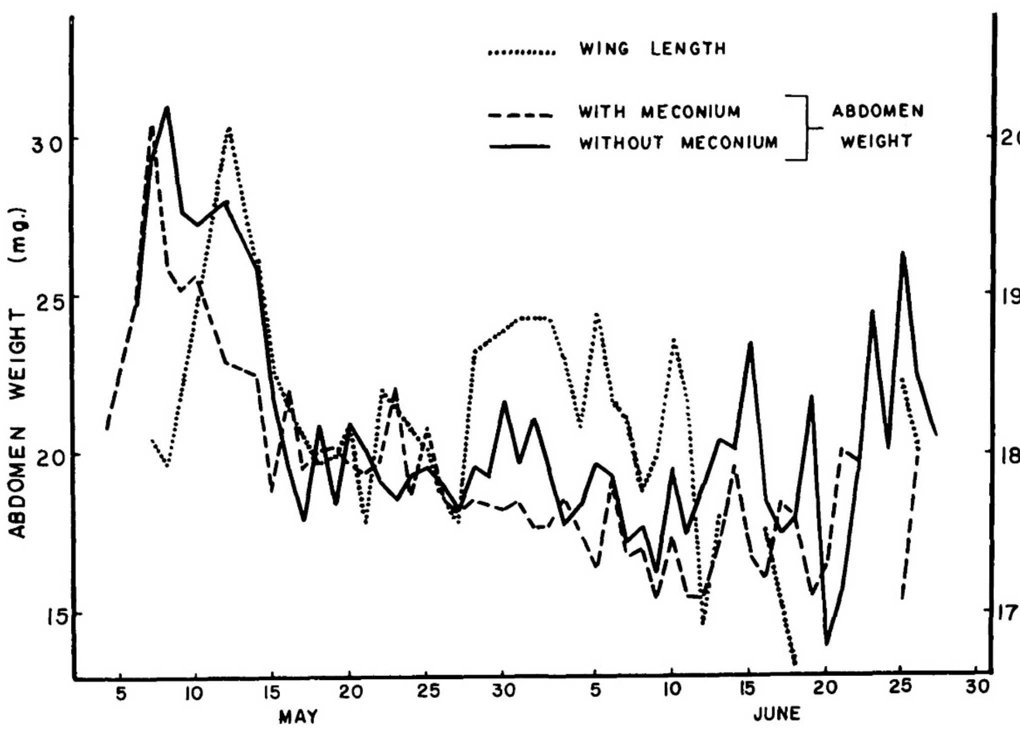

Figure 5. Seasonal changes in mean wing length and abdomen weight of female army cutworm moths, North Platte, Nebraska, 1964.

My conclusion is that, following eclosion, moths undergo very slight changes in weight while active on the Plains. Accumulation of such reserves must occur during the summer, and daily changes in mean moth size and weight on the Plains can be explained only by a constant turnover in the population.

Reproduction

Females which have mated or contain mature eggs have never been collected, even in the mountains, before late August, when fall activity also resumes on the Plains. Table 6 summarizes frequency of mating and egg development during the fall at several locations arranged from west to east.

Table 6. Mating frequency and egg development of female army cutworm moths collected at light during fall

Location, west to east	No. moths examined[a]	Mean egg development[b]	Percent unmated	Mean times mated
		1959		
Centennial	20	0.5	55	0.6
Scottsbluff	28	1.1	7	1.5
North Platte	316		14	1.2
		1960		
Centennial	50	.4	80	.2
Scottsbluff	218	1.2	9	2.0
Bushnell	389	1.5	6	1.5
Alliance	621	1.4	3	1.7
North Platte	881	1.2	1	1.8
Kearney	60	1.3	0	2.0
		1963		
Centennial	7	1.2	14	.8
Laramie	26	1.4	0	1.2
Cheyenne	115	1.3	3	1.5
Bushnell	352	1.4	0	1.9
Ogallala	99	1.6	0	1.7
North Platte	496	1.6	2	1.8
Kearney	402	1.5	0	1.5
		1964		
Centennial	20	.1	80	.2
Cheyenne	143	1.2	10	1.1
Scottsbluff	48	1.0	10	1.1
Bushnell	171	1.5	2	1.3
Chappell	146	1.4	2	1.2
Ogallala	128	1.3	3	1.2
North Platte	402	1.4	3	1.3
Kearney	84	1.2	0	1.2

a. Minimum number for any measurement.
b. Rated 0 to 3; 0 = large fat body but no egg development; 3 = < 50 mature eggs and fat body exhausted.

Relatively few mated females have been collected in the light trap at Centennial and those which have mated usually contain only immature eggs. On the Plains, most moths are mated when collected, but frequency of mating varies little from west to east. Except for the rare unmated female, these moths usually contain mature eggs. These results confirm the previous conclusion that little or no reproduction occurs in the mountains despite the presence of moths. If sexually immature moths are taken at light in the mountains, why are prereproductive stages so rarely collected on the Plains in the fall? The evidence is that those moths collected on the Plains had mated and developed eggs prior to their activity there.

Yearly Changes in Distribution

The normal distribution of the species, considering only those on the eastern side of the Rocky Mountains, is within about 480 km of the mountains. Distribution fluctuates from year to year, the eastern range occasionally being greatly extended. Areas of high populations one year may be devoid of moths the following season. This situation has occurred several times at Lincoln, Nebraska, where the species may be quite abundant one year and absent the next. I have attempted to correlate spring and fall moth flights at various locations. Data for North Platte and Centennial are given in Table 7.

Table 7. Spring and fall light-trap catches at North Platte, Nebraska, and Centennial, Wyoming

	North Platte		Centennial
Year	Spring	Fall	(spring)
1959	35,255	2,086	332
1960	8,643	4,991	532
1961	59,204	9,072	1,051
1962	11,055	14,380	3,641
1963	43,206	9,142	3,369
1964	27,881	1,786	251
1965	4,789	3,008	497

There is no correlation between size of the spring and succeeding fall flight at North Platte, nor have I been able to find such a relationship at any other location on the Plains. However, the fall flight at North Platte is correlated with size of the flight at Centennial the preceding spring. In general, the fall flight on the Plains is proportional to the size of the oversummering population in the Rocky Mountains.

Other Evidence for Migration

Koerwitz and Pruess (1964) studied the flight ability of the army cutworm and found that the species was potentially capable of the proposed migration. Of the Noctuidae studied, the army cutworm possessed the greatest flight potential (Koerwitz 1961).

In Part II of this series of papers I shall present evidence confirming the observation of Pepper (1932) that an oriented spring flight occurs. In Nebraska and Wyoming, spring movement appears to be from east to west.

Discussion and Conclusions

Moths of the army cutworm cannot be found on the central Great Plains for an interval of 30 days or longer each summer. All moths emerge in the spring but eggs are not laid until fall. The evidence is conclusive that only one generation occurs. Two hypotheses are proposed to explain the bimodal seasonal activity of moths. These are: (1) an in situ estivation of moths on the Great Plains, or (2) migration of moths to the Rocky Mountains with return of the same individuals. Other alternatives have not been proposed, nor can I think of one which would logically explain the biology, behavior, and distribution of the species.

In the eastern portion of the range, activity of moths in the spring coincides with known emergence, as indicated by the large number of young moths still retaining the meconium which are collected in light traps. Percent of moths possessing meconium tends to decline to the west, and the spring flight occurs progressively later to the west. While this delay in moth activity is partially caused by delayed emergence, a successively higher proportion of light trap catches to the west, especially near the end of the spring activity period, cannot be correlated with any known emergence of moths. This phenomenon could be explained by a delay caused by migration from east to west, and it is commensurate with the flight ability of the moth. Spring flights of moths appear to be unidirectionally oriented from east to west.

Moths possessing meconium have not been collected in the Rocky Mountains, and I assume no moths emerge there. However, moths become abundant in the Rocky Mountains during the summer and the period of activity in the mountains coincides with the period of inactivity on the Great Plains.

Experimental evidence indicates that few or no moths are physically capable of surviving the summer on the central Great Plains. If they do survive, they must do so in an inactive estivation. Food has been found important for adult survival, and longevity varies inversely with temperature. Moths are known to be active in the mountains during this critical period on the Plains and are most abundant near alpine meadows at high altitudes, where neither food nor temperature requirements would be limiting factors.

Moths collected on the Plains during the fall have larger fat reserves than spring-collected moths. Such reserves could not be accumulated during an inactive estivation. On the Plains moths are never collected during the spring with fat reserves greater than those known to be present at the time of emergence. However, there is an accumulation of fat reserves by moths occurring in the mountains during the summer which is commensurate with the reserves found in moths which reappear on the Plains during the fall.

Most females collected on the Plains in the fall are mated and contain mature eggs. Moths collected at the same time in the mountains are largely unmated and, if mated, contain only immature eggs. This difference is most easily reconciled by assuming that egg maturation occurs between the mountains and the Plains.

Distribution and abundance of the species fluctuates. Fall populations cannot be correlated with populations the preceding spring at any locality on the Plains. But fall populations on the Plains are directly related to size of the oversummering populations in the Rocky Mountains.

In essence, I have chosen between 2 mutually exclusive hypotheses: (1) moths migrate, or (2) moths do not migrate. Only the hypothesis that moths migrate satisfactorily explains the observed phenomena. My conclusion is that the army cutworm oviposits only on the Great Plains in the fall, that moths migrate to the Rocky Mountains following emergence the next spring, and that the same individuals return to the Plains again in the fall.

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